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Regional Climatic Model RegCM User's Guide

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Chapter 1

Release Notes

RegCM-4.4 is a new step in recoding the RegCM model after the effort put into the RegCM4 version. The code base now is actively developed by a community of developers internal and external to ICTP, and this work is merged on the Gforge site on gforge.ictp.it site.

The main new technical features of the code are summarized in the following points:

- A number of new global models input layers have been added to preproc stage, and we plan to support any request to add a new layer. What is needed is just send us a couple of months worth of data, specify format if not netCDF, fix a naming convention. Just ask, we will help you. Now supported at SST stage:

  1. GISST Met Office's Global Ice coverage and Sea Surface Temperatures This data required a pre-processing (from ASCII to binary), and are available from ICTP up to 2002 from clima-dods server
  2. NOAA Optimal Interpolation SST dataset
  3. ECMWF Era Interim SST dataset
  4. CMIP5 global ocean model datasets:
     (a) Canadian Centre for Climate Modelling and Analysis CanESM2
     (b) Met Office Hadley Centre HadGEM2-ES
     (c) Commonwealth Scientific and Industrial Research Organization Mk3.6
     (d) EC-EARTH consortium (need conversion from GRIB to netCDF)
     (e) Institut Pierre-Simon Laplace CM5A-MR
     (f) NOAA Geophysical Fluid Dynamics Laboratory ESM2M
     (g) Centre National de Recherches Mtorologiques CM5 model
     (h) Max-Planck-Institut fr Meteorologie MPI-ESM-MR
  5. ECHAM 5 dataset (A1B in binary format from ICTP, A2 converted from GRIB to netCDF using cdo)
  6. 33 years Era Interim average available from ICTP

  Code for FV model and some CAM 2/4 is present, but is obsolete or untested. Supported at ICBC stage:

  1. ERA Interim and ERA 40 reanalysis
  2. NNRP reanalysys (V1 and V2)
  3. CMIP5 global atmosphere model datasets:
     (a) Canadian Centre for Climate Modelling and Analysis CanESM2
     (b) Met Office Hadley Centre HadGEM2-ES
     (c) Commonwealth Scientific and Industrial Research Organization Mk3.6
     (d) EC-EARTH consortium (need conversion from GRIB to netCDF)
     (e) Institut Pierre-Simon Laplace CM5A-MR

(f) NOAA Geophysical Fluid Dynamics Laboratory ESM2M
(g) Centre National de Recherches Mtorologiques CM5 model
(h) Max-Planck-Institut fr Meteorologie MPI-ESM-MR

4. ECHAM 5 dataset (A1B in binary format from ICTP, A2 converted from GRIB to netCDF using cdo)
5. 33 years Era Interim average available from ICTP

Code for FV model and some CAM 2/4 is present, but is obsolete or untested.

- Boundary conditions / emissions for tracers both aerosols and chemically active creation from different sources
- 2D model decomposition is fully tested and model scales easily up to 512 processors what was scaling previously up to 64 processors.
- RCP standard 2.6, 4.5, 6.0 and 8.5 Greenhouse gas concentration data for historical and future scenarios.
- A new option to use measured total solar irradiance from SOLARIS instead of the previously used hardcoded solar constant.
- Climatological and future 2.6, 4.5 and 8.5 scenario data for ozone concentration.
- The CLM 4.5 surface scheme basic physics option is coupled to the RegCM model.
- The Ocean coupling is now hadled with a module which allows the RegCM code to be used as an external library into the RegESM package.
- Experimental new empirical cumulus cloud representation option.
- In the model output each file tipology can be disabled, and in each file each output 2D/3D variable can be disable. The default is to write all the defined variables, but the user may play with the `enable_xxx_vars` flags to eventually disable variables. Some variables cannot be disabled: xlat , xlon , mask , topo , ps. Those are needed for model geolocation.
- Model input is read now in parallel by all processors, i.e. a complete diskless model for computing nodes is not supported: each processor needs access to the input data directory.
- Model output can be written in parallel by the model taking advantage of a parallel file system and the mpiio capability of the HDF5 library. Model must be compiled with the `--enable-nc4-parallel` flag and the namelist option `do_parallel_netcdf_io` must be set to true. As to take advantage from this a particular harware/software stack is needed, this is NOT the default option.
- Model output files contain when applicable geolocation informations following the CF-1.6 convention. IDV can now use this informations, except for the rotated mercator projection which is unsupported in the java IDV library.
- Model output variable naming convention and unit of measure shouldi respect the CORDEX experiment guidelines. User should report any non-conformity.
- The Kallen 1996 algorithm is used to compute Mean Sea Level pressure.
- A Gauss-Seidel smoothing has been applied to the Mean Sea Level and the Geopotential Height post-processing calculation subroutines.

Bug Fixing:

- Cressman type interpolation is used for all Gaussian grids in SST/ICBC
- Added extra stratospheric layers in the RRTM radiation model.

- Model input/output of netCDF files is consistent at all stages using a common library.
- Fix for tracer gases optical properties in the visible spectra
- Relaxing upstream scheme for cloud disabled as it may need reworking.
- The GrADSNc programs now is able to guess when the data are monthly averages calculated with cdo and use 1mo as timestep in the ctl file
- All model output is now using the write intrinsic instead of print.
- A long standing bug in the computation of drag coefficient have been fixed.

Next release V 5.X :

- New dynamical core from Giovanni Tumolo semi-implicit, semi-Lagrangian, p-adaptive Discontinuous Galerkin method three dimensional model.

The model code is in Fortran 2003 ANSI standard. The development is done on Linux boxes, and the model is known to run on Oracle Solaris™platforms, IBM AIX™platforms, MacOS™platforms. No porting effort has been done towards non Unix-like Operating Systems. We will for this User Guide assume that the reference platform is a recent Linux distributon with a `bash` shell. Typographical convention is the following:

Table 1.1: Conventions

`$>`	normal shell prompt
`#>`	root shell prompt
`$SHELL_VARIABLE`	a shell variable

Any shell variable is supposed to be set by the User with the following example syntax:

```
$> export REGCM_ROOT="/home/user/RegCM4.4-rc13"
```

Hope you will find this document useful. Any error found belongs to me and can be reported to be corrected in future revisions. Enjoy.

Chapter 2

Obtaining the model

2.1 Simple Model User

A packed archive file with the model code can be downloaded from:

`http://gforge.ictp.it/gf/project/regcm/frs`

and it can be later on decompressed and unpacked using:

```
$> tar -zxvf RegCM-4.4.0.tar.gz
```

2.2 Model Developer

If you plan to become a model developer, source code can be obtained via svn. The RegCM team strongly encouragethe contributing developers to enroll on the gforge site to always be up to date and to check on-line all the news of the package.

https://gforge.ictp.it/gf/project/regcm

The correct procedure is first to register on the G-forge site, then ask the ICTP scientific team head Filippo Giorgi to be enrolled as a model developer. After being officially granted the status, you will gain access to the model subversion repository.

Check that **Subversion** software is installed on your machine typing the following command:

```
$> svn --version
```

If your system answers `command not found`, refer to your System Administrator or software installation manual of your OS to install the subversion software. As an example, on Scientific Linux the command to install it as root is:

```
#> yum install subversion
```

If Subversion is installed, just type the following command:

```
$> svn checkout https://gforge.ictp.it/svn/regcm/branches/regcm-core
```

Chapter 3

Installation procedure

Whatever method is chosen to download the code, we assume that you have now on your working directory a new directory, named `RegCM-4.4.x`. That directory will be for the rest of this guide referred as `$REGCM_ROOT` .

All the operations to build the model binaries will be performed in this directory.

3.1 Software requirements

In order to configure and install the RegCM code, the following software are needed:

1. GNU Make program
2. Fortran 2003 compiler
3. One in:
   (a) C compiler for the serial option (`enable-mpi-serial` at configure)
   (b) MPI2 Message Passing Library compiled with the above fortran compiler for parallel runs using multiple core single machines or cluster of machines (default). Source code for the implementation code was tested with can be obtained at:
   http://www.open-mpi.org
4. netCDF (*Rew and Davis* (1990)) Format I/O library compiled with the above Fortran compiler. Source code can be found from
   ftp://ftp.unidata.ucar.edu/pub/netcdf

Optional requirements strongly suggested are :

1. HDF5 Format I/O Library compiled with the above fortran compiler to enable netCDF V4 features. Source code can be obtained at:
   http://www.hdfgroup.org/ftp/HDF5/current/src
   Note that some of the input datasets available from ICTP from 2012 DO require this option, as we distribute data in the netCDF V4 format. Note that current netCDF version 4.3.1.1/4.2 is dependent on HDF5 1.8.12.
2. NCO netCDF Operators for manging netCDF file. Most Linux distribution have this already packed, and you should refer to your System Administrator or OS Software Installation manual to obtain it. Source code is at:
   http://nco.sourceforge.net/src
3. CDO Climatic data Operators for managing netCDF file. Most Linux distribution have this already packed, and you should refer to your System Administrator or OS Software Installation manual to obtain it. Source code is at:
   https://code.zmaw.de/projects/cdo/files

4. A Scientific Plotting and Data Analysis Software such as:

   - IGES GrADS 2.0 Graphical Analysis and Display System. Convenient helpers are packed in RegCM to use GrADS with RegCM netCDF output files. Binaries and source code can be obtained from **http://www.iges.org/grads/downloads.html**
   - NCL, NCAR CISL Command Language. The NCL can read netCDF output files, and sample scripts can be found in the *Tools/Scripts/NCL* directory. Binaries and source code can be obtained from **http://www.ncl.ucar.edu**

5. A quick viewer for netCDF files like NcView:
   http://meteora.ucsd.edu/ pierce/ncview_home_page.html

A script is shipped in the RegCM codebase in the Tools directory to help user compile and install required packages, and its usage is detailed in chapter 9.

3.2 Configuring build

The RegCM Version 4.4 is configured by a configure script, which will select the known working configuration for the supported architectures.

Currently tested and supported configurations (OS/Compiler) are:

1. Linux with GNU gfortran compiler version $\geq$ 4.6
2. Linux with Intel^{TM}ifort compiler version $\geq$ 12.0
3. Linux with Portland^{TM}pgf95 compiler version $\geq$ 11.0
4. Mac OsX^{TM}with gfortran compiler $\geq$ 4.6 from MacPorts
5. IBM AIX^{TM}with xlf2003 compiler

The 4.4 version of the RegCM model relies on the standard GNU autotools to configure and build the model code.

The first step is to change working directory to `$REGCM_ROOT` and run the `configure` script giving as arguments the chosen compilers:

```
$> cd $REGCM_ROOT
$> ./configure CC=icc FC=ifort
```

To know the list of arguments that can be given to the configure script, the script can be launched with the `--help` command line argument.

```
$> ./configure --help
```

The useful arguments to successfully build the model are:

```
  --with-netcdf           Path to NetCDF installation (default: NETCDF
                          environment)
  --with-hdf5             Path to HDF5 installation (default: HDF5
                          environment)
  --with-szip             Path to SZIP installation (default: SZIP
                          environment)
  CC=         C compiler command
  CFLAGS=     C compiler flags
  LDFLAGS=    linker flags, e.g. -L<lib dir> if you have libraries in a
              nonstandard directory <lib dir>
```

```
LIBS=       libraries to pass to the linker, e.g. -l<library>
CPPFLAGS=   (Objective) C/C++ preprocessor flags, e.g. -I<include dir> if
            you have headers in a nonstandard directory <include dir>
CPP=        C preprocessor
FC=         Fortran compiler command
FCFLAGS=    Fortran compiler flags
MPIFC=      MPI Fortran compiler command
```

3.2.1 Model configuration at build stage

1. Enable debug

   ```
   --enable-debug     Enable debugging flags and per processor log file
   ```

   If enabled, the model will be compiled using debug flags for the compiler, which will allow the use of a debugger such as gdb. More diagnostics will also be generated during model run. The default is to build production binaries with all optimization flags turned on.

2. Serial code using stub MPI library

   ```
   --enable-mpiserial Use the included MPI replacement library for single
                      processor
   ```

   The model is coded to use an MPI2 library to run in parallel mode using multiple cores/processors or run on a cluster. To enable instead a serial compilation option, a stub MPI library with empty callbacks needs to be compiled and linked to the executable. The RegCM team strongly suggest to build MPI enabled model also on standalone systems, to take advantage of the multicore capabilities of any modern processor.

3. CLM option

   ```
   --enable-clm       Supply this option if you plan on using CLM option.
   ```

   This option switches off the default Land model of RegCM (derived from BATS1e), and enables the use of the Community Land Model V3.5 inside RegCM. The default is to use the RegCM BATS Land Model.

4. CLM 4.5 option

   ```
   --enable-clm45     Supply this option if you plan on using CLM45 option.
   ```

   This option switches off the default Land model of RegCM (derived from BATS1e), and enables the use of the Community Land Model V4.5 inside RegCM. The default is to use the RegCM BATS Land Model.

3.3 Build the model executables

Now that everything is hopefully configured, you may use the `make` program to build executables.

```
$> make
```

This target will builds all model parts. The compilation is started in the whole model tree (PreProc, Main and PostProc). Lot of messages will appear on screen, abd at the end all executables are built int the source directories. To copy them to a `bin` directory in the model root or into a `bin` directory in the path specified with the prefix argument to the `configure` script, esplicitly issue the command:

```
$> make install
```

Congratulations! You can now go to next step and run a test simulation.

Chapter 4

Accessing global datasets

The first step to run a test simulation is to obtain static data to localize model DOMAIN and Atmosphere and Ocean global model dataset to build initial and boundary conditions ICBC to run a local area simulation.

ICTP maintains a public accessible web repository of datasets on:

http://clima-dods.ictp.it/data/d8/cordex

We will in the following substitute this URL with a shell variable:

```
$> export ICTP_DATASITE=http://clima-dods.ictp.it/data/d8/cordex
```

As of now you are requested to download required global data on your local disk storage before any run attempt. In the future, the ICTP ESP team has planned to make available an OpenDAP THREDDS Server to give remote access to global dataset for creating DOMAIN and ICBC without the need to download the global dataset, but just the required subset in space and time, using the ICTP web server capabilities to create that subset.

Our advice to you is to use handy transfer program such as uget, but below we will show you how to use command line download tools curl and wget to get data.

4.1 Global dataset directory Layout

You are suggested to establish a convenient location for global datasets on your local storage. Keep in mind that required space for a year of global data can be as large as 8 GBytes.

Having this in mind, we will now consider that you the user have identified on your system or have network access to such a storage resource to store say 100 GB of data, and have it reachable on your system under the `$REGCM_GLOBEDAT` location. On this directory, you are required to make the following directories:

```
$> cd $REGCM_GLOBEDAT
$> mkdir SURFACE CLM CLM45 SST EIN15
```

This does not fill all possible global data sources paths, but will be enough for the scope of running the model for testing its capabilities.

4.2 Static Surface Dataset

The model needs to be localized on a particular DOMAIN. The needed information are topography, land type classification and optionally lake depth (to run the Hostetler lake model) and soil texture classification (to run the chemistry option with DUST enabled).

This means downloading four files, which are global archives at 30*second* horizontal resolution on a global latitude-longitude grid of the above data.

```
$> cd $REGCM_GLOBEDAT
$> cd SURFACE
$> curl -o GTOPO_DEM_30s.nc ${ICTP_DATASITE}/SURFACE/GTOPO_DEM_30s.nc
$> curl -o GLCC_BATS_30s.nc ${ICTP_DATASITE}/SURFACE/GLCC_BATS_30s.nc
```

Optional Lake and Texture datasets:

```
$> cd $REGCM_GLOBEDAT
$> cd SURFACE
$> curl -o ETOPO_BTM_30s.nc ${ICTP_DATASITE}/SURFACE/ETOPO_BTM_30s.nc
$> curl -o GLZB_SOIL_30s.nc ${ICTP_DATASITE}/SURFACE/GLZB_SOIL_30s.nc
```

4.3 CLM Dataset

If you are planning to enable the `CLM` option in the model, you will need a series of files with global land surface characteristics datasets.

```
$> cd $REGCM_GLOBEDAT
$> cd CLM
$> curl -o mksrf_fmax.nc ${ICTP_DATASITE}/CLM/mksrf_fmax.nc
$> curl -o mksrf_glacier.nc ${ICTP_DATASITE}/CLM/mksrf_glacier.nc
$> curl -o mksrf_lai.nc ${ICTP_DATASITE}/CLM/mksrf_lai.nc
$> curl -o mksrf_lanwat.nc ${ICTP_DATASITE}/CLM/mksrf_lanwat.nc
$> curl -o mksrf_navyoro_20min.nc ${ICTP_DATASITE}/CLM/mksrf_navyoro_20min.nc
$> curl -o mksrf_pft.nc ${ICTP_DATASITE}/CLM/mksrf_pft.nc
$> curl -o mksrf_soicol_clm2.nc ${ICTP_DATASITE}/CLM/mksrf_soicol_clm2.nc
$> curl -o mksrf_soitex.10level.nc ${ICTP_DATASITE}/CLM/mksrf_soitex.10level.nc
$> curl -o mksrf_urban.nc ${ICTP_DATASITE}/CLM/mksrf_urban.nc
$> curl -o pft-physiology.c070207 ${ICTP_DATASITE}/CLM/pft-physiology.c070207
$> curl -o pft-physiology.c070207.readme \
> ${ICTP_DATASITE}/CLM/pft-physiology.c070207.readme
$> curl -o rdirc.05.061026 ${ICTP_DATASITE}/CLM/rdirc.05.061026
```

This is the input file for the `clm2rcm` program (see at 6.2).

4.4 CLM 4.5 Dataset

If you are planning to enable the `CLM 4.5` option in the model, you will need a series of files with global land surface characteristics datasets.

```
$> cd $REGCM_GLOBEDAT
$> cd CLM45
$> mkdir megan pftdata snicardata surface
$> for dir in megan pftdata snicardata surface; do cd $dir; \
    wget ${ICTP_DATASITE}/CLM45/$dir/ -O - | \
    wget -A ".nc" -l1 --no-parent --base=${ICTP_DATASITE}/CLM45/$dir/ \
      -nd -Fri -; done
```

This is the input file for the `mksurfdata` program (see at 6.3).

4.5 Sea Surface Temperature

The model needs a global SST dataset to feed the model with ocean temperature. You have multiple choices for SST data, but we will for now for our test run download just CAC OISST weekly for the period 1981 - present.

```
$> cd $REGCM_GLOBEDAT
$> cd SST
$> CDCSITE="ftp.cdc.noaa.gov/pub/Datasets/noaa.oisst.v2"
$> curl -o sst.wkmean.1981-1989.nc \
> ftp://$CDCSITE/sst.wkmean.1981-1989.nc
$> curl -o sst.wkmean.1990-present.nc \
> ftp://$CDCSITE/sst.wkmean.1990-present.nc
```

4.6 Atmosphere and Land temperature Global Dataset

The model needs to build initial and boundary conditions for the regional scale, interpolating on the RegCM grid the data from a Global Climatic Model output. The GCM dataset can come from any of the supported models, but we will for now for our test run download just the EIN15 dataset for the year 1990 (Jan 01 00:00:00 UTC to Dec 31 18:00:00 UTC)

```
$> cd $REGCM_GLOBEDAT
$> cd EIN15
$> mkdir 1990
$> cd 1990
$> for type in "air hgt rhum uwnd vwnd"
>  do
>    for hh in "00 06 12 18"
>    do
>      curl -o ${type}.1990.${hh}.nc \
>         ${ICTP_DATASITE}/EIN15/1990/${type}.1990.${hh}.nc
>    done
>  done
```

With this datasets we are now ready to go through the RegCM Little Tutorial in the next chapter of this User Guide.

Chapter 5

Running a test simulation using the model

We will in this chapter go through a sample session in using the model with a sample configuration file prepared for this task.

5.1 Setting up the run environment

The model executables prepared in chapter 3 are waiting for us to use them. So let's give them a chance.

The model test run proposed here requires around 100Mb of disk space to store the DOMAIN and ICBC in input and the output files. We will assume here that you, the user, have already established a convenient directory on a disk partition with enough space identified in the following discussion with `$REGCM_RUN`

We will setup in this directory a standard environment where the model can be executed for the purpose of learning how to use it.

```
$> cd $REGCM_RUN
$> mkdir input output
$> ln -sf $REGCM_ROOT/bin .
$> cp $REGCM_ROOT/Testing/test_001.in .
$> cd $REGCM_RUN
```

Now we are ready to modify the input namelist file to reflect this directory layout. A namelist file in FORTRAN is a convenient way to give input to a program in a formatted file, read at runtime by the program to setup its execution behaviour. So the next step is somewhat tricky, as you need to edit the namelist file respecting its well defined syntax. Open your preferred text file editor and load the `test_001.in` file. You will need to modify for the scope of the present tutorial the following lines:

```
FROM:
 dirter = '/set/this/to/where/your/domain/file/is',
TO:
 dirter = 'input/',
```

```
FROM:
 inpter = '/set/this/to/where/your/surface/dataset/is',
TO:
 inpter = '$REGCM_GLOBEDAT',
```

where `$REGCM_GLOBEDAT` is the directory where input data have been downloaded in chapter 4.

```
FROM:
 dirglob = '/set/this/to/where/your/icbc/for/model/is',
TO:
 dirglob = 'input/',
```

```
FROM:
 inpglob = '/set/this/to/where/your/input/global/data/is',
TO:
 inpglob = '$REGCM_GLOBEDAT',
```

and last bits:

```
FROM:
 dirout='/set/this/to/where/your/output/files/will/be/written'
TO:
 dirout='output/'
```

These modifications just reflect the above directory layout proposed for this tutorial, and any of these paths can point anywhere on your system disks. The path is limited to 256 characters. We are now ready to execute the first program of the RegCM model.

5.2 Create the DOMAIN file using terrain

The first step is to create the DOMAIN file to localize the model on a world region. The program which does this for you reading the global databases is `terrain` .

To launch the terrain program, enter the following commands:

```
$> cd $REGCM_RUN
$> ./bin/terrain test_001.in
```

If everything is correctly configured up to this point, the model should print something on stdout, and the last lines will be:

```
 Grid data written to output file
 Successfully completed terrain fields generation
```

In the input directory the program will write the following two files:

```
$> ls input
test_001_DOMAIN000.nc test_001_LANDUSE
```

The DOMAIN file contains the localized topography and landuse databases, as well as projection information and land sea mask. The second file is an ASCII encoded version of the landuse, used for modifying it on request. We will cover it's usage later on. To have a quick look at the DOMAIN file content, you may want to use the GrADSNcPlot program:

```
$> ./bin/GrADSNcPlot input/test_001_DOMAIN000.nc
```

If not familiar with GrADS program, enter in sequence the following commands at the `ga->` prompt:

```
ga-> q file
ga-> set gxout shaded
ga-> set mpdset hires
ga-> set cint 50
ga-> d topo
ga-> c
ga-> set cint 1
ga-> d landuse
ga-> quit
```

this will plot the topography and the landuse on the X11 window.

5.3 Create the SST using the sst program

We are now ready to create the Sea Surface Temperature for the model, reading a global dataset. The program which does this for you is the `sst` program, which is executed with the following commands:

```
$> cd $REGCM_RUN
$> ./bin/sst test_001.in
```

If everything is correctly configured up to this point, the model should print something on stdout, and the last line will be:

```
 Successfully generated SST
```

The input directory now contains a new file:

```
$> ls input
test_001_DOMAIN000.nc test_001_LANDUSE test_001_SST.nc
```

The SST file contains the Sea Surface temperature to be used in generating the Initial and Boundary Conditions for the model for the period specified in the namelist file. Again you may want to use the GrADSNcPlot program to look at file content:

```
$> ./bin/GrADSNcPlot input/test_001_SST.nc
```

If not familiar with GrADS program, enter in sequence the following commands at the `ga->` prompt:

```
ga-> q file
ga-> set gxout shaded
ga-> set mpdset hires
ga-> set cint 2
ga-> d sst
ga-> quit
```

this will plot the interpolated sst field on the X11 window.

5.4 Create the ICBC files using the icbc program

Next step is to create the ICBC (Initial Condition, Boundary Conditions) for the model itself. The program which does this for you is the `icbc` program, executed with the following commands:

```
$> cd $REGCM_RUN
$> ./bin/icbc test_001.in
```

If everything is correctly configured up to this point, the model should print something on stdout, and the last line will be:

```
 Successfully completed ICBC
```

The input directory now contains two more files:

```
$> ls -1 input
test_001_DOMAIN000.nc
test_001_ICBC.1990060100.nc
test_001_ICBC.1990070100.nc
test_001_LANDUSE
test_001_SST.nc
```

The ICBC files contain the surface pressure, surface temperature, horizontal 3D wind components, 3D temperature and mixing ratio for the RegCM domain for the period and time resolution specified in the input file. Again you may want to use the GrADSNcPlot program to look at file content:

```
$> ./bin/GrADSNcPlot input/test_001_ICBC.1990060100.nc
```

If not familiar with GrADS program, enter in sequence the following commands at the `ga->` prompt:

```
ga-> q file
ga-> set gxout shaded
ga-> set mpdset hires
ga-> set cint 2
ga-> d ts
ga-> c
ga-> set lon 10
ga-> set lat 43
ga-> set t 1 last
ga-> d ts
ga-> quit
```

this will plot the interpolated surface temperature field on the X11 window, first at first time step and then a time section in one of the domain points for a whole month.

We are now ready to run the model!

5.5 First RegCM model simulation

The model has now all needed data to allow you to launch a test simulation, the final goal of our little tutorial.

The model command line now will differ if you have prepared the Serial or the MPI version. For the MPI enabled version we will assume that your machine is a dual core processor (baseline for current machines, even for laptops). Change the `-np 2` argument to the number of processors you have on Your platform (on my laptop QuadCore I use `-np 4`).

- MPI version [1]

  ```
  $> cd $REGCM_RUN
  $> mpirun -np 8 ./bin/regcmMPI test_001.in
  ```

- Serial version [2]

  ```
  $> cd $REGCM_RUN
  $> ./bin/regcmSerial test_001.in
  ```

Now the model will start running, and a series of diagnostic messages will be printed on screen. As this is a simulation known to behave well, no stoppers will appear, so you may want now to have a coffee break and come back in 10 minutes from now.

At the end of the run, the model will print the following message:

```
 RegCM V4 simulation successfully reached end
```

The output directory now contains four files:

```
$> ls output
test_001_ATM.1990060100.nc test_001_SRF.1990060100.nc
test_001_RAD.1990060100.nc test_001_SAV.1990070100.nc
```

[1] Use regcmMPICLM if the CLM version has been configured

[2] Deprecated. Support will be dropped in future releases.

the ATM file contains the atmosphere status from the model, the SRF file contains the surface diagnostic variables, and the RAD file contains radiation fluxes information. The SAV file stores the status of the model at the end of the simulation period to enable a restart, thus allowing a long simulation period to be splitted in shorter simulations.

To have a look for example at surface fields, you may want to use the following command:

```
$> ./bin/GrADSNcPlot output/test_001_SRF.1990060100.nc
```

Assuming the previous crash course in using GraDS was received, you should be able to plot the variables in the file.

This is the end of this little tutorial, and in the next chapter we will examine how to configure the model for your research needs.

Chapter 6

Localizing the model and running your simulation

We will examine in this chapter in more detail the namelist configuration file, to give you the User a deeper knowledge of model capabilities.

6.1 The commented namelist

In this section we will show you the commented namelist input file you will find under `$REGCM_ROOT/Doc` with the name `README.namelist` . All model programs seen so far, with the exception of the GrADS helper program, use as input this namelist file, which is unique to a particular simulation. The model input namelist file is composed by a number of different namelists, each one devoted to configuring the model capabilities. A namelist in the namelist file is identified with a starting `&` character followed by namelist name, and ends on a single line with the `\` character.

6.1.1 dimparam namelist

This namelist contains the base X,Y,Z domain dimension information, used by the model dynamic memory allocator to request the Operating System the memory space to store the model internal variables.

```
&dimparam
iy     = 34,   ! This is number of points in the N/S direction
jx     = 48,   ! This is number of points in the E/W direction
kz     = 18,   ! Number of vertical levels
dsmin  = 0.01, ! Minimum sigma spacing (only used if kz is not 14, 18, or 23)
dsmax  = 0.05, ! Maximum sigma spacing (only used if kz is not 14, 18, or 23)
nsg    = 1,    ! For subgridding, number of points to decompose. If nsg=1,
               ! no subgridding is performed. CLM3.5 does NOT work with
               ! subgridding enabled.
/
```

The things you need to know here:

1. In the current version 4.4 the model parallelizes execution dividing the work between the processors, with the minimum work per processor is 9 points or a box $3*3$, so the maximum number of processors which can be used in a parallel run for the above configuration is roughly 180.
2. If a custom number of sigma level is chosen (not 14, 18 or 23), the actual sigma values are calculated mimimizing the a, b coefficients for the equation:

$$dsig(i) = dsmax * a^{i-1} * b^{0.5*(i-2)*(i-1)} \tag{6.1}$$

derived from the recursive relation:

$$dsig(i) = a(i) * dsig(i-1) \tag{6.2}$$

where $a(i) = b * a(i-1)$. We at ICTP normally use 18 levels.

3. Specifying an nsg number greater than one triggers the subgrid BATS model on. There is no plan to extend this feature to CLM3.5 model. This affects only surface variable calculations. All dynamical variables are calculated still on the coarser grid. Rain in the current implementation is also calculated on the coarser grid.

6.1.2 geoparam namelist

This namelist is used by the `terrain` program to geolocate the model grid on the earth surface. The RegCM model uses a limited number of projection engines. The value here are used by the other model programs to assert consistency with the geolocation information written by the `terrain` program in the `DOMAIN` file.

The first step in any application is the selection of model domain and resolution. There are no strict rules for this selection, which in fact is mostly determined by the nature of the problem and the availability of computing resources. The domain should be large enough to allow the model to develop its own circulations and to include all relevant forcings and processes, and the resolution should be high enough to capture local processes of interest (e.g. due to complex topography or land surface).

On the other hand the model computational cost increases rapidly with resolution and domain size, so a compromise needs to be usually reached between all these factors.

This is usually achieved by experience, understanding of the problem or trial and error, however one tip to remember is to avoid that the boundaries of the domain cross major topographical systems.

This is because the mismatch in the resolution of the coarse scale lateral driving fields and the model fields in the presence of steep topography may generate spurious local effects (e.g. localized precipitation areas) which can affect the model behavior, at least in adjacent areas.

```
&geoparam
iproj = 'LAMCON', ! Domain cartographic projection. Supported values are:
                  ! 'LAMCON', Lambert conformal.
                  ! 'POLSTR', Polar stereographic. (Doesn't work)
                  ! 'NORMER', Normal  Mercator.
                  ! 'ROTMER', Rotated Mercator.
ds = 60.0,        ! Grid point horizontal resolution in km
ptop = 5.0,       ! Pressure of model top in cbar
clat = 45.39,     ! Central latitude  of model domain in degrees
                  ! North hemisphere is positive
clon = 13.48,     ! Central longitude of model domain in degrees
                  ! West is negative.
plat = 45.39,     ! Pole latitude (only for rotated Mercator Proj)
plon = 13.48,     ! Pole longitude (only for rotated Mercator Proj)
truelatl = 30.0,  ! Lambert true latitude (low latitude side)
truelath = 60,    ! Lambert true latitude (high latitude side)
i_band = 0,       ! Use this to enable a tropical band. In this case the ds,
                  ! iproj, clat, clon parameters are not considered.
/
```

The things you need to know here:

1. The different projection engines produce better results depending on the position and extent of the domain. In particular, regardless of hemisphere:
   - Middle latitudes (around 45 degrees) - Lambert Conformal
   - Polar latitudes (more than 75 degrees) - Polar Stereographic
   - Low latitudes (up to 30 degrees and crossing the equator) - Mercator
   - Crossing more than 45 degrees extent in latitude - Rotated Mercator
2. The model hydrostatic engine does not allow a resolution lower than $20km$. If you want a higher resolution consider using the subgridding scheme. ICTP plans to introduce in the future a non-hydrostatic compressible core to the RegCM model.

3. Lowering the top pressure of the model can give you problems in regions with complex topography. Touch the default after thinking twice on that.

4. Always specify `clat` and `clon`, the central domain point, and do fine adjustment of the position moving it around a little bit. A little shift in position and some tests can help you obtain a better representation of coastlines and topography at the coarse resolutions.

5. If using `LAMCON` projection, take care to place the two true latitudes at around one fourth and three fourth of the domain latitude space to better correct the projection distortion of the domain.

6. The pole position for the rotated mercator position should be as near as possible to the center domain position.

7. For the `i_band` parameter, selecting this will enable the tropical band experiment, and the horizontal resolution will be calculated from the number of jx points. The projection is set to Normal Mercator, the center of the projection is set to `clat = 0.0`, `clon = 180.0`, and the grid point resolution is calculated as:

$$\frac{2 * \pi * 6370.0}{jx} \tag{6.3}$$

   Just remember:

   (a) The model for a tropical band simulation is heavy, as the number of points is usually huge to obtain a good horizontal resolution. Check any memory limit is disabled on your platform before attempting a run.

   (b) The model scales well on a cluster with a large number of processors.

6.1.3 terrainparam namelist

This namelist is used by the `terrain` program to know how you want to generate the `DOMAIN` file. You can control its work using a number of parameters to obtain what you consider the best representation of the physical reality. Do not underestimate what you can do at this early stage, having a good representation of the surface can lead to valuable results later when the model calculates climatic parameters.

```
&terrainparam
domname  = 'AQWA',      ! Name of the domain. Controls naming of input files
smthbdy = .false.,      ! Smoothing Control flag
                        !  true  -> Perform extra smoothing in boundaries
lakedpth    = .false.,  ! If using lakemod (see below), produce from
                        ! terrain program the domain bathymetry
ltexture    = .false.   ! If using DUST tracer (see below), produce from
                        ! terrain program the texture soil dataset
lsmoist     = .false.,  ! Use Satellite Soil Moisture Dataset for
                        ! initialization of soil moisture.
fudge_lnd   = .false.,  ! Fudging Control flag, for landuse of grid
fudge_lnd_s = .false.,  ! Fudging Control flag, for landuse of subgrid
fudge_tex   = .false.,  ! Fudging Control flag, for texture of grid
fudge_tex_s = .false.,  ! Fudging Control flag, for texture of subgrid
fudge_lak   = .false.,  ! Fudging Control flag, for lake of grid
fudge_lak_s = .false.,  ! Fudging Control flag, for lake of subgrid
h2opct = 50.,           ! Surface minimum H2O percent to be considered water
h2ohgt = .false.,       ! Allow water points to have elevation greater than 0
ismthlev = 1,           ! How many times apply the 121 smoothing
dirter = 'input/',      ! Output directory for terrain files
inpter = 'globdata/',   ! Input directory for SURFACE dataset
/
```

The things you need to know here:

1. The `domname` will control the output file naming convention, all generated files will add this prefix to the old V3 naming convention, giving you the capability to recognize different runs. Try to use always meaningful names.

2. You can control the final land-water mask using the h2opct parameter. This parameter can be used to have more land points than calculated by the simple interpolation engine. Try it with different values to find best land shapes. A zero value means use just the interpolation engine, higher values will extend into ocean points the land at land-water interface. The h2ohgt parameter allows also water points to have elevation greater than zero to avoid wall effects on the coasts.

3. A number of flags control the capability of the `terrain` program to modify on request the class type variables in the `DOMAIN` file. You can modify on request the landuse, the texture and the lake/land interface. Running once the `terrain` program, it will generate for you aside from the `DOMAIN` file a series of ASCII files you can modify with any text editor. Running the `terrain` program the second time and setting a `fudge` flag, will tell the program to overwrite the selected variable with the modified value in the ASCII file. This can be useful for sensitivity experiments in the BATS surface model or to design a scenario experiment.

4. Some of the land surface types in BATS have been little tested and used or are extremely simplified and thus should be used cautiously. Specifically the types are: sea ice, bog/marsh, irrigated crop, glacier. If such types are present in a domain, the user is advised to carefully check the model behavior at such points and eventually substitute these types with others.

5. The `inpter` directory is expected to contain a `SURFACE` directory where the actual netCDF global dataset are stored. The overall path is limited to 256 characters.

6. If the netCDF library is compiled with OpenDAP support, an URL can be used as a path in the `dirter` and `inpter` variables. Note that the 256 character limit for paths holds in the whole program. For `terrain` program you may want to try the following URL:
http://clima-dods.ictp.it/thredds/dodsC

6.1.4 debugparam namelist

This namelist is used by all RegCM programs to enable/disable some debug printout. In the current release this flag is honored only by the model itself. If you are not a developer you may find this flags useless.

```
&debugparam
debug_level = 0, ! Currently value of 2 and 3 control previous DIAG flag
dbgfrq = 3,      ! Interval for printout if debug_level >= 3
/
```

Just note that with current implementation, the output file syncing is left to the netCDF library. If You want to examine step by step the output while the model is running, set the `debug_level` at value 3.

6.1.5 boundaryparam namelist

Being a limited area model, in order to be run RegCM4 requires the provision of meteorological initial and time dependent lateral boundary conditions, typically for wind components, temperature, water vapor and surface pressure. These are obtained by interpolation from output from reanalysis of observations or global climate model simulations, which thus drive the regional climate model.

The lateral boundary conditions (LBC) are provided through the so called relaxation/diffusion technique which consists of:

1. selecting a lateral buffer zone of n grid point width (`nspgx`)

2. interpolating the driving large scale fields onto the model grid

3. applying the relaxation + diffusion term

$$\frac{\partial \alpha}{\partial t} = F(n)F_1 * (\alpha_{LBC} - \alpha_{mod}) - F(n)F2 * \Delta_2(\alpha_{LBC} - \alpha_{mod}) \tag{6.4}$$

where α is a prognostic variable (wind components, temperature, water vapor, surface pressure). The first term on the rhs is a Newtonian relaxation term which brings the model solution (*mod*) towards the LBC field

(*LBC*) and the second term diffuses the differences between model solution and LBC. $F(n)$ is an exponential function given by:

$$F(n) = exp\left(\frac{-(n-1)}{anudge(k)}\right) \tag{6.5}$$

Where n is the grid point distance from the boundary (varying from 1 to *nspgx*): $n-1$ is the outermost grid point, $n=2$ the adjacent one etc. The *anudge* array determines the strength of the LBC forcing and depends on the model level k. In practice $F(n)$ is equal to 1 at the outermost grid point row and decreases exponentially to 0 at the internal edge of the buffer zone (*nspgd*) at a rate determined by *anudge*. Larger buffer zones and larger values of *anudge* will yield a greater forcing by the LBC.

Typically for domain sizes of 100 grid points we use a buffer zone width of $10-12$ grid points, for large domains this buffer zone can increase to values of 15 or even 20.

In the model *anudge* has three increasing values from the lower, to the mid and higher troposphere. For example for $nspgx = 10$ we use *anudge* equals to $1,2,3$ for the lower, mid and upper troposphere, respectively.

This allows a stronger forcing in the upper troposphere to insure a greater consistency of large scale circulations with the forcing LBC while allowing more freedom to the model in the lower troposphere where local high resolution forcings (e.g. complex topography) are more important.

For nspgx of $15-20$, for example, *anudge* values could be increased to $2,3,4$. As a rule of thumb, the choice of the maximum *anudge* value should follow the conditions:

$$\frac{(nspgx-1)}{anudge(k)} \geq 3 \tag{6.6}$$

```
&boundaryparam
nspgx  = 12, ! nspgx-1 represent the number of cross point slices on
             ! the boundary sponge or relaxation boundary conditions.
nspgd  = 12, ! nspgd-1 represent the number of dot point slices on
             ! the boundary sponge or relaxation boundary conditions.
high_nudge   =     3.0, ! Nudge value high range
medium_nudge =     2.0, ! Nudge value medium range
low_nudge    =     1.0  ! Nudge value low range
/
```

6.1.6 globdatparam namelist

This namelist is used by the `sst` and `icbc` ICBC programs. You can tell them how to build initial and bondary conditions.

```
&globdatparam
ibdyfrq =     6,            ! boundary condition interval (hours)
ssttyp = 'OI_WK',           ! Type of Sea Surface Temperature used
                            !  One in: GISST, OISST, OI2ST, OI_WK, OI2WK,
                            !          FV_A2, FV_B2, EH5A2, EH5B1, EHA1B,
                            !          EIN75, EIN15, ERSST, ERSKT, CCSST,
                            !          CA_XX, HA_XX, EC_XX, IP_XX, GF_XX,
                            !          CN_XX
dattyp = 'EIN15',           ! Type of global analysis datasets used
                            !  One in: ECMWF, ERA40, EIN75, EIN15, EIN25,
                            !          ERAHI, NNRP1, NNRP2, NRP2W, GFS11,
                            !          FVGCM, FNEST, EH5A2, EH5B1, EHA1B,
                            !          CCSMN, ECEXY, CA_XX, HA_XX, EC_XX,
                            !          IP_XX, GF_XX, CN_XX, MP_XX
gdate1 = 1990060100,        ! Start date for ICBC data generation
gdate2 = 1990070100,        ! End data for ICBC data generation
calendar = 'gregorian',     ! Calendar to use (gregorian, noleap or 360_day)
dirglob = 'input/',         ! Path for ICBC produced input files
inpglob = 'globdata/',      ! Path for ICBC global input datasets.
ensemble_run = .false.,     ! If this is a member of a perturbed ensemble
                            ! run. Activate random noise added to input
                ! Look http://users.ictp.it/~pubregcm/RegCM4/globedat.htm
                ! on how to download them.
/
```

Things you need to know here:

1. The gdate time window to build ICBC must be always greater or equal to the time window you plan to run the model in. Different GCMs and reanalysis products have different length of the year. For example, the reanalysis products employ the real year length (365 days + real leap years, i.e. and average length of 365.2422), the CCSM has a length of 365 days (no leap year), the HadCM has a length of 360 days (30 day months). The RegCM4 length of the year has to be the same as in the forcing fields, and this can be set in the variable `dayspy`. Please remember to always check the consistency of the length of the year.

2. Even if listed, not all the input engines are fully tested. Some of them need data which have been reformatted by ICTP (they are not in the original format with which they are distributed by the institution producing them). Some input data are not freely distibutable by ICTP, and you need a special agreement with the owner to use them. Hopefully the situation is changing, and data exchange is becoming more and more the basis for good science in the climatic field.

3. For notes on path, you can see the above in terrainparam namelist description at 5.

6.1.7 fnestparam namelist

This namelist is read if the `FNEST` is selected as `dattyp` in `globdatparam` namelist (see above in 6.1.6), and permits the user to specify the output directory of the coarse resolution run already completed and the name of the coarse domain, i.e. the `domname` namelist parameter used in the `terrainparam` coarse namelist (see above in 6.1.3).

The nested domain must be contained inside the coarse domain, and possibly the nested domain should not overlap the boundary region of the coarse run. Those checks are left to the user.

If nothing is specified or namelist not present default is to search for a directory `RegCM` inside `inpglob` directory for files without a `domname`, i.e. like `ATM.YYYYMMDDHH.nc`.

```
!
! Nesting control
!
 &fnestparam
 coarse_outdir = 'globdata/RegCM', ! Coarse domain output dir if FNEST
 coarse_domname = 'EUROPE',        ! Coarse domain domname
 /
```

6.1.8 perturbparam namelist

This namelist lets you control to which input field and of what fractional level a perturbation is added at ICBC stage on the input fields. It is read by the ICBC program if the `ensemble_run` parameter in the `globdatparam` namelist is set to `true`.

```
!
! Perturbation control for ensembles
!
 &perturbparam
 lperturb_topo = .false.,     ! Add perturbation to surface elevation
 perturb_frac_topo = 0.001D0, ! Fractional value of the perturbation on topo
 lperturb_ts = .false.,       ! Add perturbation to surface temeprature
 perturb_frac_ts = 0.001D0,   ! Fractional value of the perturbation on ts
 lperturb_ps = .false.,       ! Add perturbation to surface pressure
 perturb_frac_ps = 0.001D0,   ! Fractional value of the perturbation on ps
 lperturb_t  = .false.,       ! Add perturbation to temperature
 perturb_frac_t  = 0.001D0,   ! Fractional value of the perturbation on t
 lperturb_q  = .false.,       ! Add perturbation to humidity mixing ratio
 perturb_frac_q  = 0.001D0,   ! Fractional value of the perturbation on q
 lperturb_u  = .false.,       ! Add perturbation to zonal velocity
 perturb_frac_u  = 0.001D0,   ! Fractional value of the perturbation on u
 lperturb_v  = .false.,       ! Add perturbation to meridional velocity
 perturb_frac_v  = 0.001D0,   ! Fractional value of the perturbation on v
 /
```

Things you need to know here:

1. The `perturb_frac` should not exceed a percent of the field value. The algorithm detail of the applied noise can be found in *O'Brien et al.* (2011).

6.1.9 restartparam namelist

This namelist lets you control the time period the model is currently simulating in this particular run. You may want to split longer runs for which you have prepared the ICBC's into shorter runs, to schedule HPC resource usage in a more collaborative way with other researcher sharing it: the regcm model allows restart, so be friendly with other research projects which may not have this fortune (unless you are late for publication).

```
&restartparam
ifrest  = .false. ,   ! If a restart
mdate0  = 1990060100, ! Global start (is gdate1, most probably)
mdate1  = 1990060100, ! Start date of this run
mdate2  = 1990060200, ! End date for this run
/
```

Things you need to know here:

1. After the simulation starts, on restart NEVER change the `mdate0` value. The correct scheme for restart is:
   - Set `ifrest` to `.true.`
   - Set `mdate1` to the value in `mdate2`
   - Define the new value for `mdate2`
2. Consider that current RegCM convention is to place midnight of first day of month as the last timestep in previous month, except on first model output file (`ifrest = .false.`). It is for this reason better to use as start and end time a month boundary. We usually consider a month data file the basic unit of output, each time you cross a month a new output file will be created for you.

6.1.10 timeparam namelist

This namelist contains model internal timesteps, used by the model as basic integration timestep and triggers for calling internal parametric schemes.

```
&timeparam
dt     =   150., ! time step in seconds
dtrad  =    30., ! time interval solar radiation calculated (minutes)
dtabem =    18., ! time interval absorption-emission calculated (hours)
dtsrf  =   600., ! time interval at which land model is called (seconds)
/
```

Things you need to know here:

1. The dynamical hydrostatical core of RegCM requires a fixed timestep, and you need to manually find the correct value which permits not to break the CourantFriedrichsLewy condition considering *R. Courant and Lewy* (1928). A good rule of thumb is to have a `dt` not greater than three times the `ds` value in *km* specified in the `geoparam` namelist at 6.1.2. A greater value may lower computing time, but in case of strong advection may lead to non accurate computation or even the violation of CFL condition and the divergence of the solution.
2. All the other internal timesteps need to be multiples of the base timestep. Note that the units are different, so you need to convert the other timesteps in seconds before the check.
3. In case of strong surface gradients, a low value for the surface timesteps may help the model better describe the interaction with the atmosphere and obtain a stable solution.
4. If you hit a non stable condition, the restart capability of the model may help find the correct timestep just for a particular period, using a different timestep at different times.

6.1.11 outparam namelist

This namelist controls the model output engine, allowing you to enable/disable any of the output file writeout, or to modify the frequency the fields are written in the files.

```
&outparam
ifsave  = .true. ,           ! Create SAV files for restart
savfrq  =    48.,            ! Frequency in hours to create them
ifatm   = .true. ,           ! Output ATM ?
atmfrq  =     6.,            ! Frequency in hours to write to ATM
ifrad   = .true. ,           ! Output RAD ?
radfrq  =     6.,            ! Frequency in hours to write to RAD
ifsts   = .true. ,           ! Output STS (frequence is daily) ?
ifsrf   = .true. ,           ! Output SRF ?
srffrq  =     3.,            ! Frequency in hours to write to SRF
ifsub   = .true. ,           ! Output SUB ?
subfrq  =     6.,            ! Frequency in hours to write to SUB
iflak   = .true.,            ! Output LAK ?
lakfrq  =     6.,            ! Frequency in hours to write to LAK
ifchem  = .true.,            ! Output CHE ?
ifopt   = .false.,           ! Output OPT ?
chemfrq =     6.,            ! Frequency in hours to write to CHE
enable_atm_vars = 64*.true., ! Mask to eventually disable variables ATM
enable_srf_vars = 30*.true., ! Mask to eventually disable variables SRF
enable_rad_vars = 23*.true., ! Mask to eventually disable variables RAD
enable_sub_vars = 17*.true., ! Mask to eventually disable variables SUB
enable_sts_vars = 17*.true., ! Mask to eventually disable variables STS
enable_lak_vars = 18*.true., ! Mask to eventually disable variables LAK
enable_opt_vars = 13*.true., ! Mask to eventually disable variables OPT
enable_che_vars = 24*.true., ! Mask to eventually disable variables CHE
dirout  = './output',        ! Path where all output will be placed
lsync   = .false.,           ! If sync of output files at every timestep is
                             ! requested. Note, it has a performance impact.
                             ! Enabled by default if debug_level > 2
idiag = 0,                   ! Enable tendency diagnostic output in the ATM
                             ! file. NOTE: output file gets HUGE.
do_parallel_netcdf_in  = .false., ! This enables paralell input
                                  ! Each processors reads its slice in the
                                  ! input file. Enable ONLY in case of
                                  ! HUGE input bandwidth,
do_parallel_netcdf_out = .false., ! This enables paralell output if the
                                  ! hdf5/netcdf libraries support it and
                                  ! the model is compiled with :
                                  !    --enable-nc4-parallel
/
```

Things you need to know here:

1. The surface fields are the mean values in the interval specified by the frequency values. The dynamical fields are instead the point value at the output time. Refer to the Reference Manual *Giorgi* (2011) for a detailed description of the model output fields.

2. If the chemistry or lake model are not enabled, the values specified in the control flags are not considered. If `nsg` is not greater than one in dimparam at 6.1.1, the `ifsub` flag is not considered.

3. For the output directory, the path variable has a limit of 256 characters. This path must be a local path on disk where the user running the model has write permissions granted.

4. The enablevar logical arrays can be used to avoid saving one of the time dependent variables in the output file, in the order they are saved in the output file itself. Note that geolocation and pressure variables cannot be disabled.

6.1.12 physicsparam namelist

This namelist controls the model physics. You have a number of option here, and the best way to select the right set is to carefully read the the Reference Manual *Giorgi* (2011). We are for the purposes of this User Guide not going in detail in here, except in saying that probably you will need to run some experiments especially with different cumulus convection schemes before finding out the best model setting. Although the mixed convection scheme (Grell over land and Emanuel over ocean) seems to provide an overall better performance, our experience is that there is no scheme that works best everywhere, therefore we advice to always do some sensitivity experiments to select the best scheme for your application.

```
&physicsparam
iboudy  =          5,  ! Lateral Boundary conditions scheme
                       !   0 => Fixed
                       !   1 => Relaxation, linear technique.
                       !   2 => Time-dependent
                       !   3 => Time and inflow/outflow dependent.
                       !   4 => Sponge (Perkey & Kreitzberg, MWR 1976)
                       !   5 => Relaxation, exponential technique.
isladvec =         0,  ! Semilagrangian advection scheme for tracers and
                       ! humidity
                       !   0 => Disabled
                       !   1 => Enable Semi Lagrangian Scheme
ibltyp  =          1,  ! Boundary layer scheme
                       !   0 => Frictionless
                       !   1 => Holtslag PBL (Holtslag, 1990)
                       !   2 => UW PBL (Bretherton and McCaa, 2004)
icup_lnd =          4, ! Cumulus convection scheme Over Land
icup_ocn =          4, ! Cumulus convection scheme Over Icean
                       !   1 => Kuo
                       !   2 => Grell
                       !   3 => Betts-Miller (1986) DOES NOT WORK !!!
                       !   4 => Emanuel (1991)
                       !   5 => Tiedtke (1996)
                       !   6 => Kain-Fritsch (1990), Kain (2004)
  igcc  =          1,  ! Grell Scheme Cumulus closure scheme
                       !   1 => Arakawa & Schubert (1974)
                       !   2 => Fritsch & Chappell (1980)
ipptls  =          1,  ! Moisture scheme
                       !   1 => Explicit moisture (SUBEX; Pal et al 2000)
                       !   2 => Explicit moisture Nogherotto/Tompkins
iocnflx =          2,  ! Ocean Flux scheme
                       !   1 => Use BATS1e Monin-Obukhov
                       !   2 => Zeng et al (1998)
                       !   3 => Coare bulk flux algorithm (snowice),
                       !        only activated with coupling
  iocnrough =      1,  ! Zeng Ocean model roughness formula to use.
                       !   1 => (0.0065*ustar*ustar)/egrav
                       !   2 => (0.013*ustar*ustar)/egrav + 0.11*visa/ustar
ipgf    =          0,  ! Pressure gradient force scheme
                       !   0 => Use full fields
                       !   1 => Hydrostatic deduction with pert. temperature
iemiss  =          0,  ! Use computed long wave emissivity
lakemod =          0,  ! Use lake model
ichem   =          1,  ! Use active aerosol chemical model
scenario =      'A1B', ! IPCC Scenario to use in A1B,A2,B1,B2
                       ! RCP Scenarios in RPC2.6,RCP4.5,RCP6,RCP8.5
idcsst   =         0,  ! Use diurnal cycle sst scheme
iseaice  =         0,  ! Model seaice effects
idesseas =         0,  ! Model desert seasonal albedo variability
iconvlwp =         0,  ! Use convective liquid water path as the large-scale
                       ! liquid water path
irrtm    =         0,  ! Use RRTM radiation scheme instead of CCSM
iclimao3 =         0,  ! Use O3 climatic dataset from SPARC CMIP5
isolconst =        1,  ! Use a constant 1367 W/m^2 instead of the prescribed
                       ! TSI recommended CMIP5 solar forcing data.
```

```
islab_ocean =       0, ! Activate the SLAB ocean model
itweak =            0, ! Enable tweak scenario
\
```

6.1.13 subexparam namelist

This namelist controls the SUBEX moisture scheme. Please consider carefully reporting in your work the tuning you perform on this parameters. The parameters below are the ones currently used at ICTP.

```
&subexparam
ncld      =         1, ! # of bottom model levels with no clouds
qck1land  =   .250E-03, ! Autoconversion Rate for Land
qck1oce   =   .250E-03, ! Autoconversion Rate for Ocean
gulland   =       0.4, ! Fract of Gultepe eqn (qcth) when precip occurs
guloce    =       0.4, ! Fract of Gultepe eqn (qcth) for ocean
rhmax     =      1.01, ! RH at whicn FCC = 1.0
rh0oce    =      0.90, ! Relative humidity threshold for ocean
rh0land   =      0.80, ! Relative humidity threshold for land
tc0       =     238.0, ! Below this temperature, rh0 begins to approach unity
cevaplnd  =   .100E-02, ! Raindrop evap rate coef [[(kg m-2 s-1)-1/2]/s]
cevapoce  =   .100E-02, ! Raindrop evap rate coef [[(kg m-2 s-1)-1/2]/s]
caccrlnd  =     3.000, ! Raindrop accretion rate [m3/kg/s]
caccroce  =     3.000, ! Raindrop accretion rate [m3/kg/s]
cllwcv    =    0.3E-3, ! Cloud liquid water content for convective precip.
clfrcvmax =      1.00, ! Max cloud fractional cover for convective precip.
cftotmax  =      0.75, ! Max total cover cloud fraction for radiation
/
```

We found that RegCM4 is especially sensitive to:

1. `cevap` : increasing cevap will generally decrease precipitation
2. `gulland`, `guloce` : increase of guland/guloce will generally lead to reduce precipitation

6.1.14 microparam namelist

This namelist controls the new microphysics scheme.

```
&microparam
 budget_compute = .false.,  ! Verify enthalpy and moisture conservation
 nssopt = 1,                ! Supersaturation Computation
                            ! 0 => No scheme
                            ! 1 => Tompkins
                            ! 2 => Lohmann and Karcher
                            ! 3 => Gierens
 kautoconv = 4,             !  Choose the autoconversion paramaterization
                            ! => 1 Klein & Pincus (2000)
                            ! => 2 Khairoutdinov and Kogan (2000)
                            ! => 3 Kessler (1969)
                            ! => 4 Sundqvist
 ksemi = 1.0D0,             ! Implicit/Explicit control
                            ! NOT ACTIVATED YET - IT DOES NOT WORK!
                            ! ksemi == 0 => scheme is fully explicit
                            ! ksemi == 1 => scheme is fully implicit
                            ! 0<ksemi<1  => scheme is semi-implicit
 vqxr = 4.0D0,              ! Rain fall speed (default is 4 m/s)
 vqxi = 0.15D0,             ! Ice fall speed (default is 0.15 m/s)
 vqxs = 1.0D0,              ! Snow fall speed (default is 1 m/s)
 zauto_rate_khair = 0.355D0,! Autoconversion coefficient for kautoconv=2
 zauto_rate_kessl = 1.D-3,  ! Autoconversion coefficient for kautoconv=3
 zauto_rate_klepi = 0.5D-3, ! Autoconversion coefficient for kautoconv=1
 rkconv = 1.666D-4,         ! Autoconversion coefficient for kautoconv=4
 rcovpmin = 0.1D0,          ! Minimum precipitation coverage
 rpecons = 5.547D-5,        ! Evaporation constant Kessler
/
```

6.1.15 grellparam, emanparam, tiedtkeparam and kfparam namelists

You are allowed here to tune the convection scheme selected above in 6.1.12 with the `icup_lnd` or `icup_ocn` number if selected number is $2, 4, 5$.

```
&grellparam
shrmin = 0.25,       ! Minimum Shear effect on precip eff.
shrmax = 0.50,       ! Maximum Shear effect on precip eff.
edtmin = 0.25,       ! Minimum Precipitation Efficiency
edtmax = 0.50,       ! Maximum Precipitation Efficiency
edtmino = 0.25,      ! Minimum Precipitation Efficiency (o var)
edtmaxo = 0.50,      ! Maximum Precipitation Efficiency (o var)
edtminx = 0.25,      ! Minimum Precipitation Efficiency (x var)
edtmaxx = 0.50,      ! Maximum Precipitation Efficiency (x var)
shrmin_ocn = 0.25,   ! Minimum Shear effect on precip eff. OCEAN points
shrmax_ocn = 0.50,   ! Maximum Shear effect on precip eff.
edtmin_ocn = 0.25,   ! Minimum Precipitation Efficiency
edtmax_ocn = 0.50,   ! Maximum Precipitation Efficiency
edtmino_ocn = 0.25,  ! Minimum Precipitation Efficiency (o var)
edtmaxo_ocn = 0.50,  ! Maximum Precipitation Efficiency (o var)
edtminx_ocn = 0.25,  ! Minimum Precipitation Efficiency (x var)
edtmaxx_ocn = 0.50,  ! Maximum Precipitation Efficiency (x var)
pbcmax = 150.0,      ! Max depth (mb) of stable layer b/twn LCL & LFC
mincld = 150.0,      ! Min cloud depth (mb).
htmin = -250.0,      ! Min convective heating
htmax = 500.0,       ! Max convective heating
skbmax = 0.4,        ! Max cloud base height in sigma
dtauc = 30.0,        ! Fritsch & Chappell (1980) ABE Removal Timescale (min)
/

&emanparam
minsig = 0.95,       ! Lowest sigma level from which convection can originate
elcrit_ocn = 0.0011, ! Autoconversion threshold water content (g/g) over ocean
elcrit_lnd = 0.0011, ! Autoconversion threshold water content (g/g) over land
tlcrit = -55.0,      ! Below tlcrit auto-conversion threshold is zero
entp = 1.5,          ! Coefficient of mixing in the entrainment formulation
sigd = 0.05,         ! Fractional area covered by unsaturated dndraft
sigs = 0.12,         ! Fraction of precipitation falling outside of cloud
omtrain = 50.0,      ! Fall speed of rain (Pa/s)
omtsnow = 5.5,       ! Fall speed of snow (Pa/s)
coeffr = 1.0,        ! Coefficient governing the rate of rain evaporation
coeffs = 0.8,        ! Coefficient governing the rate of snow evaporation
cu = 0.7,            ! Coefficient governing convective momentum transport
betae = 10.0,        ! Controls downdraft velocity scale
dtmax = 0.9,         ! Max negative parcel temperature perturbation below LFC
alphae = 0.2,        ! Controls the approach rate to quasi-equilibrium
damp = 0.1,          ! Controls the approach rate to quasi-equilibrium
epmax_ocn = 0.999,   ! Maximum precipitation efficiency (ocean)
epmax_lnd = 0.999,   ! Maximum precipitation efficiency (land)
/

&tiedtkeparam
iconv = 4,           ! Actual used scheme.
entrmax = 1.75D-3,   ! Max entrainment iconv=[1,2,3]
entrdd  = 3.0D-4,    ! Entrainment rate for cumulus downdrafts
entrpen = 1.75D-3,   ! Entrainment rate for penetrative convection
entrscv = 3.0D-4,    ! Entrainment rate for shallow convection iconv=[1,2,3]
entrmid = 1.0D-4,    ! Entrainment rate for midlevel convection iconv=[1,2,3]
cprcon = 1.0D-4,     ! Coefficient for determining conversion iconv=[1,2,3]
detrpen = 0.75D-4,   ! Detrainment rate for penetrative convection iconv=4
entshalp = 2.0D0,    ! shallow entrainment factor for entrorg iconv=4
rcuc_lnd = 0.05D0,   ! Convective cloud cover for rain evporation iconv=4
rcuc_ocn = 0.05D0,   ! Convective cloud cover for rain evporation iconv=4
rcpec_lnd = 5.55D-5, ! Coefficient for rain evaporation below cloud iconv=4
rcpec_ocn = 5.55D-5, ! Coefficient for rain evaporation below cloud iconv=4
rhebc_lnd = 0.7D0,   ! Critical rh below cloud for evaporation iconv=4
rhebc_ocn = 0.9D0,   ! Critical rh below cloud for evaporation iconv=4
```

```
rprc_lnd = 1.4D-3,   ! conversion coefficient from cloud water iconv=4
rprc_ocn = 1.4D-3,   ! conversion coefficient from cloud water iconv=4
/

&kfparam
kf_trigger = 3,      ! Trigger mechanism. Allowed values 1 and 3
kf_entrate = 0.03D0, ! Entrainment rate
/
```

Things you need to know here:

1. In case of the mixed schemes $96, 97, 98, 99$, both the selected schemes configuration namelist are read in. Note in this case for the schemes only the relevant (Ocean or Land) control values are used.

2. Minimum and maximum values of the fraction of reevaporated water in the downdraft for the Grell scheme is essentially a measure of the precipitation efficiency: increasing their value generally decrease convective precipitation.

3. Again, read carefully the Reference Manual before attempting any tuning, and report in any work modification of this parameters.

6.1.16 holtslagparam namelist

You are allowed here to tune the Holtslag PBL scheme selected above in 6.1.12 with the `ibltyp` number if selected number is 1.

```
&holtslagparam
ricr_ocn = 0.25D0,  ! Critical Richardson Number over Ocean
ricr_lnd = 0.25D0,  ! Critical Richardson Number over Land
zhnew_fac = 0.25D0, ! Multiplicative factor for zzhnew in holtpbl
/
```

6.1.17 uwparam namelist

You are allowed here to tune the UW PBL scheme selected above in 6.1.12 with the `ibltyp` number if selected number is 2.

```
&uwparam
iuwvadv = 0,     ! 0=standard T/QV/QC advection, 1=GB01-style advection
                 ! 1 is ideal for MSc simulation, but may have stability issues
atwo = 15.0D0,   ! Efficiency of enhancement of entrainment by cloud evap.
                 !  see Grenier and Bretherton (2001) Mon. Wea. Rev.
                 !  and Bretherton and Park (2009) J. Clim.
rstbl = 1.5D0,   ! Scaling parameter for stable boundary layer eddy length
                 ! scale.  Higher values mean stronger mixing in stable
                 ! conditions
czero = 5.869D0, ! Czero constant in UW PBL (eqn 44a and pgs 856-857)
/
```

6.1.18 slabocparam namelist

Here you define parameter and stage fot the Ocean q-flux adjusted mixed layer model.

```
&slabocparam
do_qflux_adj  = .false.,  ! Activate SLAB Ocean model surface fluxes adjust
                          ! from an already created climatology
do_restore_sst = .true.,  ! Create during the run the SLAB Ocean model surface
                          ! fluxes climatology to be used in a subsequent run
sst_restore_timescale = 5.0D0,  ! Time interval in days in building the
                                ! q-flux adjustment
mixed_layer_depth     = 50.0D0, ! Depth in meters of the Ocean mixed layer.
/
```

6.1.19 tweakparam namelist

This namelist controls the tweaking of the model to obtain custom scenarioes, Is enabled if itweak is 1 in 6.1.12.

```
&tweakparam
 itweak_sst = 0,              ! Enable adding sst_tweak to input TS
 itweak_temperature = 0,      ! Enable adding temperature_tweak to input T
 itweak_solar_irradiance = 0, ! Add solar_tweak to solar constant
 itweak_greenhouse_gases = 0, ! Multiply gas_tweak_factors to GG concentrations
 sst_tweak = 0.0D0,           ! In K
 temperature_tweak = 0.0D0,   ! In K
 solar_tweak = 0.0D0,         ! In W m-2 (1367.0 is default solar)
 gas_tweak_factors = 1.0D0, 1.0D0 , 1.0D0 , 1.0D0 , 1.0D0,
 !                   CO2    CH4     N2O     CFC11   CFC12
```

6.1.20 rrtmparam namelist

You are allowed here to tune the RRTM radiative scheme selected above in 6.1.12 with the `irrtm` number if selected number is 1.

```
 &rrtmparam
 inflgsw  = 2, ! 0 = use the optical properties calculated in prep_dat_rrtm
               !     (same as standard radiation)
               ! 2 = use RRTM option to calculate cloud optical properties
               !     from water path and cloud drop radius
 iceflgsw = 3, ! Flag for ice particle specification
               !   0 => ice effective radius, r_ec, (Ebert and Curry, 1992),
               !        r_ec must be >= 10.0 microns
               !   1 => ice effective radius, r_ec, (Ebert and Curry, 1992),
               !        r_ec range is limited to 13.0 to 130.0 microns
               !   2 => ice effective radius, r_k, (Key, Streamer Ref. Manual,
               !        1996), r_k range is limited to 5.0 to 131.0 microns
               !   3 => generalized effective size, dge, (Fu, 1996),
               !        dge range is limited to 5.0 to 140.0 microns
               !        [dge = 1.0315 * r_ec]
 liqflgsw = 1, ! Flag for liquid droplet specification
               !   0 => Compute the optical depths due to water clouds in ATM
               !        (currently not supported)
               !   1 => The water droplet effective radius (microns) is input
               !        and the optical depths due to water clouds are computed
               !        as in Hu and Stamnes, J., Clim., 6, 728-742, (1993).
 inflglw  = 2, ! Flag for cloud optical properties as above but for LW
 iceflglw = 3, ! Flag for ice particle specification as above but for LW
 liqflglw = 1, ! Flag for liquid droplet specification as above but for LW
 idrv = 0,     ! Flag for calculation of dFdT, the change in upward flux as
               ! a function of surface temperature [0=off, 1=on]
 icld  = 1,    ! Cloud Overlap hypothesis
 irng = 1,     ! mersenne twister random generator for McICA COH
 /
```

6.1.21 chemparam namelist

This namelist controls the chemistry and aerosol options in the RegCM model.

```
 &chemparam
 chemsimtype = 'CBMZ    ', ! Which chemical tracers to be activated.
                           ! One in :
                           !   DUST   : Activate 4 dust bins scheme
                           !   SSLT   : Activate 2 bins Sea salt scheme
                           !   DUSS   : Activate DUST +SSLT
                           !   CARB   : Activate 4 species black/anthropic
                           !            carbon simulations
                           !   SULF   : Activate SO2 and SO4 tracers
                           !   SUCA   : Activate both SUKF and CARB
                           !   AERO   : Activate all DUST, SSLT, CARB and SULF
                           !   CBMZ   : Activate gas phase and sulfate
```

```
                        !   DCCB   : Activate CBMZ +DUST +CARB
                        !   POLLEN : Activate POLLEN transport scheme
 ichsolver = 1,  ! Activate the gas phase chemical solver CBMZ
 ichsursrc = 1,  ! Enable the emissions fluxes.
 ichdrdepo = 1,  ! 1 = enable tracer surface dry deposition. For dust,
                 !     it is calculated by a size settling and dry
                 !     deposition scheme. For other aerosol,a dry
                 !     deposition velocity is simply prescribed further.
 ichebdy = 1,    ! Enable reading of chemical boundary conditions, otherwise put 0 in boundary conditions.
 ichcumtra = 1,  ! 1 = enable tracer convective transport.
 ichremlsc = 1,  ! 1 = enable tracer rainout
 ichremcvc = 1,  ! 1 = enable tracer washout
 ichdustemd = 1, ! Choice for parametrisation of dust emission size distribution
                 ! 1 = use the standard scheme (Alfaro et al., Zakey et al.)
                 ! 2 = use a revised soil granulometry ref +
                 !     Kok et al emission size distribution : Menut et al.,2012; + Kok et al., 2011
 ichdiag = 0,    ! 1 = enable writing of additional tracer tendency diagnostics in the output
 idirect   = 1,  ! CHoice to enable or not aerosol feedbacks on radiation and
                 ! dynamics (aerosol direct and semi direct effects): possible choice 1 or 2:
                 ! 1 = no coupling to dynamic and thermodynamic. However
                 !     the clear sky surface and top of atmosphere
                 !     aerosol radiative forcings are diagnosed.
                 ! 2 = allows aerosol feedbacks on radiative,
                 !     thermodynamic and dynamic fields.
 iindirect = 0,  ! Enable sulfate first indirect effect in radiation scheme based on Qian et al., 2001
 rdstemfac = 1.0,! Dust emission adjustment factor ( soil erodibility) : linearly reduce or increase the dust flux
 /
```

The `chemsimtype` parameter select one in a number of fixed sets which define the nature and number of chemical species and/or transported aerosols, together with wich relevant scheme is to be used in the simulation. The implemented possible simulation types for the aerosol/chemistry options are:

1. `DUST` : Activate 4 dust bins scheme, with on line emission, transport and removal.

2. `SSLT` : Activate 2 sea salt bins scheme, with on line emission, transport and removal.

3. `DUSS` : Activate Dust and seasalt scheme, 6 tracers.

4. `CARB` : Activate 4 species organic and black carbon in both hydrophobic and hydrophilic aerosol scheme, with on line emission, transport and removal.

5. `SULF` : Activate SO2 and SO4 tracers with simple sulfate oxidation from oxidant climatology, with on line emission, transport and removal.

6. `SUCA` : Activate both SULF and CARB.

7. `AERO` : Activate all DUST, SSLT, CARB and SULF

8. `CBMZ` : Activate CBMZ gas phase only option : 37 tracer are considered here.

9. `DCCB` : Activate CBMZ +DUST +CARB + sulfate-nitrate-ammonium aerosol calculated with the ISORROPIA gas-aerosol thermodynamical scheme: 50 tracers are considered here.

The more tracer are used, the heavier computationally are the simulations and the outputs. The chemistry outputs consist of one netCDF file per tracer, named explicitely and containing concentration fields + different diagnostics, and one netCDF file giving the optical properties of the total aerosol mixture i.e. aerosol optical depth and radiative forcing. For a big domain, this can require a huge amount of disk space to store the model results.

We will now detail the steps required to run a chemistry/aerosol simulation with the RegCM model.

Pre Processing

We need to perform a couple of operations in the pre-processing stage to prepare input datasets for an aerosol/chemistry simulation.

1. In the case of a `DUST`, `AERO` or `DCCB` simulation, we need the model to prepare soil type dataset to be used for dust emission calculation at the `terrain` program stage. The `ltexture` parameter in the `terrainparam` namelist (see above in 6.1.3) should be set to `.true.`.
2. After having prepared the static and boundary condition data with the `icbc` program for the atmosphere, we need also to define chemical emissions and chemical boundary conditions.

The data needed for this second task come from different sources, both measurements data or GCM model with a chemistry parametrization active.

1. Emission dataset. The pre processor can manage CMIP5 RCP and IASA anthropogenic emissions for present day and future emission. For this, the global RCP emission dataset have first been processed by ICTP to match the species considered in the chemical solver CBMZ, and to aggregate different sector of emissions that are present in the RCP fields (e.g. CO emission from biomass burning + fossil fuel + ship + ...). The resulting global files, as well as grid informations are publicly available on ICTP site :

   `http://clima-dods.ictp.it/data/d8/cordex/RCP_EMGLOB_PROCESSED`

2. Chemical boundary conditions for important tracersare available through ICTP. We use monthly boundary condition coming from global simulations (CAM + EC-EARTH) for aerosols, following different RCP scenarios (HIST + future). For gas phase species, we now have 6 hourly chemical boundary conditions issued from the MOZART CTM. Alternatively, we can use a climatology representative of monthly average concentrations over the period 2000-2007 coming from the MOZART CTM. The oxidant fields, used in the simple sulfate scheme, is also a climatology coming from MOZART CTM. The data are available on ICTP site.

The steps to prepare the chemistry boundary conditions data are the following:

1. In case of a chemistry simulation type (`CBMZ` or `DCCB`), the global emission files must first be interpolate to the RegCM model grid using the following procedure:

   - Create the RegCM model grid description file to be used by `cdo` to calculate weghts for a conservative remapping interpolation:

     ```
     $> cd $REGCM_RUN
     $> ./bin/emcre_grid test_001.in
     ```

   - Interpolate the global data on the RegCM grid with the interpolation script:

     ```
     $> cd $REGCM_RUN
     $> ./bin/interp_emissions test_001.in
     ```

   The `cdo` program installation is mandatory in this case to perform this step. The interpolation is mass conservative and is consistent for any ratio of model resolution/global emission resolution. Note the programs and script uses the same root path of `terrain` and `icbc` programs for input and data directory. By default, we expect the global emission to be at the same level than e.g. EIN15 in your data path layout. This results in a file named `*_CHEMISS.nc` of monthly emission for the whole RCP period. You dont need to reprocess the file if you change the date of your simulation, as long as you are in the RCP temporal windows (for now, Historical from 1990-2010) . Which scenario to use is controlled by the `scenario` variable in the `physicsparam` parameter namelist as above in 6.1.12

2. In function of the value of the `chemsimtype` parameter, the relevant boundary conditions will be produced on the RegCM domain by running :

```
$> cd $REGCM_RUN
$> ./bin/chem_icbc test_001.in
```

That will result in 6 hourly chemical boundary conditions in your input directory (`*_CHBC*.nc` and/or `*_AEBC*.nc`).

Run time parameters

The other `chemparam` namelist parameters, let you control run time behaviour of the model chemistry and aerosol schemes.

1. `ichsolver` : relevant for gas-phase chemistry options, activate the chemical solver CBMZ. If different from 1, there is no chemical reactions and the tracer are only emitted, transported and removed.

2. `ichsursrc` : if set different from 1, the emission term is suppressed and only boundary conditions are generating tracer in the domain.

3. `ichdrdepo` : if set different from 1, the dry deposition and sedimentation of tracers is disabled for chemistry species.

4. `ichremlsc` : if set different from 1, rainout of chemical species is disabled.

5. `ichremcvc` : if set different from 1, washout of chemical species is disabled.

6. `ichcumtra` : if set different form 1, the convective transport of tracers is disabled.

7. = `ichdiag` : if set to 1, the writing of additional diagnostics in the chemistry output is enabled. Particularly, all the 3D tendency terms (advection, turbulence, convection, boundary condition, chemistry, removal, etc.) of the tracer equation are outputted at the frequency `ichfreq`. This is usefull for budget and sensitivity studies, as well as debugging. This potentially can generate HUGE files.

8. `idirect` : Enable aerosol feedbacks on radiation.

   - if equal to 1, only aerosol radiative forcing is calculated and outputted but there is NO aerosol radiative feedback on climate. This can be viewed as a control run option.
   - if equal to 2, there is a feedback of aerosol radiative forcing on climate fields, via perturbation of the temperature tendency. This can be view as the perturbed run option.

9. `ichdustemd` : Choice for parametrisation of dust emission size distribution:

   - if set to 1, the standard scheme s used (Alfaro et al., Zakey et al., 2006)
   - if set to 2, the revised soil granulometry + Kok et al., 2011 emission size distribution is used.

10. `rdstemfac` : Scaling factor (erodibility) for tuning `DUST` emission flux

Sparse notes

1. Outputs are in netCDF, so process with your favorite software.

2. The flux and tendency variables, as well as radiative forcings, are accumulated and averaged between 2 output time steps (like precipitations). The concentration, burden and aerosol optical depth are instantaneous.

3. The outputs size can be huge, especially for full chemistry and diagnostic options. In the future, we might have the choice of outputting selected variables only.

Not every possible dynamical configuration has been tested for the chemistry option, so bugs might appear: please report! CLM enables to calculate on line biogenic volatile hydrocarbon emissions, as well as chemical deposition that can be used in RegCM. There are some flags to activate when compiling CLM, we will update the documentation when fully tested.

The Tiedke and Emmanuel schemes, when activated, offer a more detailed treatment of convective transport than the simple mixing hypothesis used with other schemes. The UW planetary boundary layer option integrate directly the emission and deposition flux terms as part of the calculation of trurbulent tracer tendency.

6.2 The CLM options

We will now discuss from the user point of view how to use the model setup which need to be activated at configure stage.

The `CLM` option if activated allows the user to run a simulation using the CLM surface model instead of the default BATS1e model. We will not here go in deep in the difference between the two models, read the Reference Manual for this. The executable of the model is different in the case of the `CLM`, and is named `regcmMPICLM`. Note that in the CLM case only the MPI enabled compilation is supported (no serial), and no subgridding is possible (`nsg` is always 1).

Enable

At configure stage (see 3.2.1), the option is to be enabled with the right command line argument to the configure script

```
--enable-clm   Supply this option if you plan on using CLM option.
```

This will enable a preprocessing flag, and build a different model executable. Note that no modifications are needed for any other part of the model, but this triggers the building of another pre-processing program, `clm2rcm`.

Prepare and run

The `CLM` configuration requires a separate namelist in the namelist input file.

```
&clmparam
dirclm = 'input/', ! CLM path to Input data produced by clm2rcm. If
                   ! relative, It should be how to reach the Input dir
                   ! from the Run dir.
clmfrq =  12.,     ! Frequency for CLM own output write
imask  =   1,      ! For CLM, Type of land surface parameterization
                   !   1 => using DOMAIN.INFO for landmask (same as BATS)
                   !   2 => using mksrf_navyoro file landfraction for
                   !        landmask and perform a weighted average over
                   !        ocean/land gridcells; for example:
                   ! tgb = tgb_ocean*(1-landfraction)+tgb_land*landfraction
/
```

Things you need to know here:

1. The `inpter` path defined in `terrainparam` namelist described in 6.1.3 is used also by the `clm2rcm` program. See at 4.3 how to obtain needed datasets.

2. The file `pft-physiology.c070207` should be manually copied in the `dirclm` directory before running the model.

3. The clmfrq is relative to the output produced by the `CLM` model itself, and does not control the RegCM model output. To know the `CLM` output file content, refer to CLM 3.5 documentation.

4. The `imask = 2` option cannot be used with the `icup_lnd` or `icup_ocn` cumulus convection schemes 2, which rely on the BATS1e landmask.

In the case of CLM run, the user needs to run, after the terrain program, the clm2rcm program, and copy the pft-physiology.c070207 in the input directory:

```
$> cd $REGCM_RUN
$> ./bin/terrain regcm.in
$> ./bin/clm2rcm regcm.in
$> cp $REGCM_GLOBEDAT/CLM/pft-physiology.c070207 input/
```

The clm2rcm program interpolates global land characteristics datasets to the RegCM projected grid. The content of the pft-physiology.c070207 file are described in the pft-physiology.c070207.readme file. All the other pre-processing steps are just equal to the one detailed in chapter 5. To run the CLM option in the RegCM model, just substitute the executable name:

```
$> mpirun -np 2 ./bin/regcmMPICLM regcm.in
```

Note that the CLM land model is much heavier than the BATS1e model, and computing time increases.

6.3 The CLM 4.5 options

We will now discuss from the user point of view how to use the model setup which need to be activated at configure stage.

The CLM 4.5 option if activated allows the user to run a simulation using the CLM version 4.5 surface model instead of the default BATS1e model. We will not here go in deep in the difference between the two models, read the Reference Manual for this. The executable of the model is different in the case of the CLM 4.5, and is named regcmMPICLM45. Note that in the CLM 4.5 case only the MPI enabled compilation is supported (no serial).

Enable

At configure stage (see 3.2.1), the option is to be enabled with the right command line argument to the configure script

```
  --enable-clm45  Supply this option if you plan on using CLM45 option.
```

This will enable a preprocessing flag, and build a different model executable. Note that no modifications are needed for any other part of the model, but this triggers the building of another pre-processing program, mksurfdata.

Prepare and run

The CLM45 configuration requires a separate entries in the namelist input file.

```
&clm_inparm
fpftcon = 'pft-physiology.c130503.nc',
fsnowoptics = 'snicar_optics_5bnd_c090915.nc',
fsnowaging = 'snicar_drdt_bst_fit_60_c070416.nc',
hist_nhtfrq = 0,
/
&clm_soilhydrology_inparm
h2osfcflag = 1,
origflag = 0,
/
&clm_hydrology1_inparm
oldfflag = 0,
/
```

Things you need to know here:

1. The namelist 6.1.6 is used also by the mksurfdata program. See at 4.4 how to obtain needed datasets.

2. The `hist_nhtfrq` is relative to the output produced by the `CLM 4.5` model itself, and does not control the RegCM model output.

3. To know the `CLM 4.5` output file content, refer to CLM 4.5 documentation.

In the case of `CLM 4.5` run, the user needs to run, after the `terrain` program, the `mksurfdata` program.

```
$> cd $REGCM_RUN
$> ./bin/terrain regcm.in
$> ./bin/mksurfdata regcm.in
$> cp $REGCM_GLOBEDAT/CLM/pft-physiology.c070207 input/
```

All the other pre-processing steps are just equal to the one detailed in chapter 5. To run the `CLM 4.5` option in the RegCM model, just substitute the executable name:

```
$> mpirun -np 2 ./bin/regcmMPICLM45 regcm.in
```

6.4 Sensitivity experiments hint

Although the LBC forcing does provide a constraint for the model, as any RCM, RegCM4 is characterized by a certain level of internal variability due to its non-liner processes (e.g. convection).

For example, if small perturbations are introduced in the initial or lateral boundary conditions, the model will generally produce different patterns of, e.g. precipitation, that appear as (sometimes seemingly organized) noise when compared to the control simulation.

This noise depends on domain size and climatic regimes, for example it is especially pronounced in warm climate regimes (e.g. tropics or during the summer season) and large doamins.

When doing for example sensitivity experiments to model modifications, e.g. to land use change, this internal variability noise can be misinterpreted as a model response to the factor modified.

Users of RegCM4 should be aware of this when they do sensitivity experiments. The best way to filter out this noise is to perform ensembles of simulations and lok at the ensemble averages to extract the real model response from the noise.

Chapter 7

Postprocessing tools

The new netCDF output format allows users to use a number of general purpose tools to postprocess model output files. We will in this section do a quick review of some of the Open Source and Free Software ones.

7.1 Command line tools

Three major set of tools may help you do even complex calculation just from command line prompt.

7.1.1 netCDF library tools

The netCDF library itself offers three basic tools to play with netCDF archived data.

- `ncdump` program, generates a text representation of a specified netCDF file on standard output. The text representation is in a form called CDL (network Common Data form Language) that can be viewed, edited, or serve as input to `ncgen`, thus `ncdump` and `ncgen` can be used as inverses to transform data representation between binary and text representations. `ncdump` may also be used as a simple browser for netCDF datasets, to display the dimension names and lengths; variable names, types, and shapes; attribute names and values; and optionally, the values of data for all variables or selected variables in a netCDF dataset. Sample usage patterns:

  1. Look at the structure of the data in the netCDF dataset:

     ```
     ncdump -c test_001_SRF.1990060100.nc
     ```

  2. Produce a fully-annotated (one data value per line) listing of the data for the variables time and tas, using FORTRAN conventions for indices, and show the floating-point data with only four significant digits of precision and the time values with ISO format:

     ```
     ncdump -v time,tas -p 4 -t -f \
             fortran test_001_SRF.1990060100.nc
     ```

- `ncgen` program, the reverse of the `ncdump` program: generates a netCDF file or a C or FORTRAN program that creates a netCDF dataset from a CDL input. Sample usage patterns:

  1. From a CDL file, generate a binary netCDF file:

     ```
     ncgen -o test_001_SRF.1990060100_modif.nc \
             test_001_SRF.1990060100.cdl
     ```

  2. From a CDL file, generate a Fortran program to write the netCDF file:

     ```
     ncgen -f test_001_SRF.1990060100.cdl > prog.f
     ```

- `nccopy` utility copies an input netCDF file to an output netCDF file, in any of the four format variants, if possible, and in function of the selected output format add compression filter and/or data chunking. Sample usage patterns:

1. Convert a netCDF dataset to a netCDF 4 classic model compressed data file using shuffling to enhance compression level:

```
nccopy -k 4 -d 9 -s test_001_SRF.1990060100.nc \
         test_001_SRF.1990060100_compressed.nc
```

You can also find, in the `Tools/Programs/RegCM_read` directory under `$REGCM_ROOT` a sample program to read an output file using the netCDF library you can modify to fit your needs.

7.1.2 NetCDF operators NCO

This set of tools can be considered a swiss army knife to manage netCDF datasets. There are multiple operators, and Each operator takes netCDF files as input, then operates (e.g., derives new data, averages, hyperslabs, manipulates metadata) and produces a netCDF output file. The single-command style of NCO allows users to manipulate and analyze files interactively, or with simple scripts that avoid some overhead of higher level programming environments. The major tools are:

- `ncap2` netCDF Arithmetic Processor
- `ncatted` netCDF Attribute Editor
- `ncbo` netCDF Binary Operator
- `ncea` netCDF Ensemble Averager
- `ncecat` netCDF Ensemble Concatenator
- `ncflint` netCDF File Interpolator
- `ncks` netCDF Kitchen Sink
- `ncpdq` netCDF Permute Dimensions Quickly, Pack Data Quietly
- `ncra` netCDF Record Averager
- `ncrcat` netCDF Record Concatenator
- `ncrename` netCDF Renamer
- `ncwa` netCDF Weighted Averager

A comprehensive user guide can be found at:

`http://nco.sourceforge.net/nco.html`

Sample usage patterns:

1. Get value of tas variable at a particular point for all timesteps with a prescribed format one per line on stdout:

```
ncks -C -H -s "%6.2f\n" -v tas -d iy,16 -d jx,16 \
         test_001_SRF.1990060100.nc
```

2. Extract one timestep of tas from a file and save into a new netCDF file:

```
ncks -c -v tas -d time,6 test_001_SRF.1990060100.nc \
       test_001_SRF.1990060212.nc
```

3. Cat together a year worth of output data for the single tas variable into a single file:

```
ncrcat -c -v tas test_001_SRF.1990??0100.nc \
         test_001_T2M.1990.nc
```

4. Get the DJF mean value of the tempertaure from a multiyear run:

```
ncra -c -v tas test_001_SRF.????120100.nc \
               test_001_SRF.????010100.nc \
               test_001_SRF.????020100.nc \
               test_001_DJF_T2M.nc
```

We strongly encourage you to read the on-line user guide of the NCO tools. You will for sure get a boost on your data manipulation and analysis skills.

7.1.3 Climate data Operators CDO

The monolithic `cdo` program from the Max Planck Institut f´ur Meteorologie implements a really comprehensive collection of command line Operators to manipulate and analyse Climate and NWP model Data either in netCDF or GRIB format. There are more than 400 operators available, covering the following topics:

- File information and file operations
- Selection and Comparision
- Modification of meta data
- Arithmetic operations
- Statistical analysis
- Regression and Interpolation
- Vector and spectral Transformations
- Formatted I/O
- Climate indices

We wont make here a comprehensive analysis of this tool, but you can find some ideas in the `PostProc` directory on `$REGCM_ROOT` reading the two sample `average` and `regrid` scripts, which use a combination of `NCO` programs and `cdo` operators to reach goal. A very simple usage pattern for example to obtain a monthly mean is:

```
cdo monmean test_001_T2M.1990.nc
```

7.2 GrADS program

This tool is the one mostly used at ICTP to analyze and plot model output results. It can be used either as an interactive tool either as a batch data analysis tool. We have already written in chapter 5 about the helper program `GrADSNcPlot` which can be used to interactively plot model output results. We will here detail why an helper program is needed and how it does work. For information regarding the `grads` program itself, a comprehensive guide may be found at:

`http://www.iges.org/grads/gadoc/users.html`

7.2.1 GrADS limits

The `grads` program is powerful, yet has limits:

1. Only the equirectangular projection or Plate Carrée is supported. Some other projections can be used through a pdef entry in the `CTL` file using the internal direct preprojection engines, but not all RegCM supported projections are supported using direct engine.

2. NetCDF format allows multidimensional variables, while `grads` supports just four dimensional (time,level,latitude,longitude) variables.

Luckily, these limits can be exceeded, carefully telling `grads` the RegCM data structure using the `CTL` file and one ancillary `proj` file:

1. The `grads` program allows usage of the `pdef BILIN` option in the `CTL` file, which allows the user to specify a supplementary file name. In this file are stored three lat-lon floating-point grids which have for each point on the equirectangular grid the indexes i,j on the projected grid, as well as wind rotation values.

2. The `grads` program allows identifying four dimentional slices of a multidimensional variable as new variables, providing them a unique name. This is how we are able to see in `grads` chemical output variables.

While the `GrADSNcPlot` program allows interactive plotting and after quitting the `grads` program removes the `CTL` file and the `proj` file, the `GrADSNcPrepare` program only creates this two files, allowing share of the `proj` file between multiple `CTL` files sharing the same RegCM domain (i.e. it creates just only once the `proj` file). To use the `grads` program, you need to have both this ancillary files together with the data netCDF file.

To create the `CTL` file for the history `CLM` output file, you need to provide to the helper programs the path to both the history `CLM` and the `RegCM DOMAIN` file, as in:

```
$ GrADSNcPrepare clmoutput.clm2.h0.2000-07-30-00000.nc test_DOMAIN000.nc
```

A collection of sample `grads` scripts commonly used at ICTP to plot simulation results can be found in the `Tools/Scripts/GrADS` directory under `$REGCM_ROOT`.

7.3 CISL's NCL : NCAR Command Language

This awesome tool from NCAR is an interpreted language designed for scientific data analysis and visualization. Noah Diffenbaugh and Mark Snyder have created a website dedicated to visualizing RegCM3 output using the NCAR Command Language (NCL). These scripts where built using RegCM3 model output converted to netCDF using an external converter. They have been adapted to serve as very basic example scripts to process a native RegCM 4.2 output data file or do some data analysis using the `NCL` language and are available in the `Tools/Scripts/NCL/examples` directory. Travis O'Brien from the User Community also contributed sample scripts, which may be found under the `Tools/Scripts/NCL` directory.

7.4 R Statistical Computing Language

The `R` statistical computing language is able with an add on package to load into interal data structure a meteorological field read from a netCDF RegCM output. A sample script to load and plot the 2m Temperature at a selected timestep can be used as a reference to develop a real powerful statistical analysis of model results: it is under `Tools/Scripts/R`.

7.5 Non free tools

Note that the netCDF format, using plugins or native capabilities, allows clean access to model output from a number of non free tools like Matlab™or IDL™.

For a more complete list of tools, you are invited to scroll down the very long list of tools at:

http://www.unidata.ucar.edu/software/netcdf/software.html

Chapter 8

Getting help and reporting bugs

8.1 The Gforge site

A new welcoming home for the RegCM Community has been built with the help of Italian National Research Council CNR Democritos Group on the e-science Lab E-Forge web site:

https://gforge.ictp.it/gf/project/regcm

Figure 8.1: The Gforge site

FORGE
Home
My Stuff
Search
Projects
Snippets
Log In | Register New Account
Welcome to gforge.ictp.it
A forge gives the ICTP people tools that promote good practices for collaborative work and that help in the dissemination of their work (inside and out of the laboratory). It permits an evolving collaboration around a project. Thanks to its associated public and private project spaces, the working environment evolves and adapts as the project does. It's a resource to help the eLab project and people in their work and its visibility.
Latest Blog posts
RegCM-4.1 released !
Posted on 2011-05-18 by cozzini
We are proud to say that RegCM-4.1 version has been released.
RegCM4.1 has the following upgrades:
Tropical band option officially enabled and documented
General bug fixing/cleaning in preprocessing/main model/postprocessing
Lake Model working again
Activity
Recently Registered Projects
(2012-02-09) xburst-tools
(2011-04-05) Lazy Builder
(2010-02-10) RegCM ICTP Regional Climate Model
Top Downloads
(6,661) RegCM ICTP Regional Climate Model
(9) xburst-tools
Browse Project Topics
Software Development (1)
Support and Docs
Local Support Project
GForge Help Forum & Docs
Office Addin Project
SOAP SDK Project
Commercial Plugins
Eclipse Project
MS Project Plugin

On this site you have access with a simple registration to a friendly bug tracking system under the *tracker* link, allowing the users to post problems and bugs they discover.

It allows posting also of files to give you the opportunity to provide as much information as possible about the environment the model is running at your institution, helping us better understand and solve efficiently your problems.

Help us grow the model to fit your requirements, giving the broader user community the benefit of a valuable tool to do better research.

Chapter 9

Appendices

We will review here a sample installation session of software needed to install the RegCM model.

The starting point is here a Linux system on a multicore processor box, and the final goal is to have an optimized system to run the model. I will use `bash` as my shell and assume that GNU development tools like `make`, `sed`, `awk` are installed as part of the default Operating System environment as is the case in most Linux distro. I will require also for commodity a command line web downloader such as `curl` installed on the system, along its development libraries to be used to enable OpenDAP remote data access protocol capabilities of netCDF library. Standard file management tools such as `tar` and `gzip` and `wget` are also required. The symbol `$>` will stand for a shell prompt. I will assume that the process is performed as a normal system user, which will own all the toolchain. I will be now just the `regcm` user.

9.1 Identify Processor

First step is to identify the processor to know its capabilities:

```
$> cat /proc/cpuinfo
```

This command will ask to the operating system to print processor informations. A sample answer on my laptop is:

```
processor       : 0
vendor_id       : GenuineIntel
cpu family      : 6
model           : 30
model name      : Intel(R) Core(TM) i7 CPU       Q 740  @ 1.73GHz
stepping        : 5
cpu MHz         : 933.000
cache size      : 6144 KB
physical id     : 0
siblings        : 8
core id         : 0
cpu cores       : 4
apicid          : 0
initial apicid  : 0
fpu             : yes
fpu_exception   : yes
cpuid level     : 11
wp              : yes
flags           : fpu vme de pse tsc msr pae mce cx8 apic sep mtrr pge
mca cmov pat pse36 clflush dts acpi mmx fxsr sse sse2 ss ht tm pbe syscall
```

```
nx rdtscp lm constant_tsc arch_perfmon pebs bts rep_good nopl xtopology
nonstop_tsc aperfmperf pni dtes64 monitor ds_cpl vmx smx est tm2 ssse3
cx16 xtpr pdcm sse4_1 sse4_2 popcnt lahf_lm ida dts tpr_shadow vnmi
flexpriority ept vpid
bogomips        : 3467.81
clflush size    : 64
cache_alignment : 64
address sizes   : 36 bits physical, 48 bits virtual
power management:
```

repeated eight time with Processor Ids from 0 to 7: I have a Quad Core Intel with Hyperthreading on (this multiply by 2 the reported processor list). The processor reports here also to support Intel Streaming SIMD Extensions V4.2, which can be later used to speed up code execution vectorizing floating point operation on any single CPU core.

9.2 Chose compiler

Depending on the processor, we can chose which compiler to use. On a Linux box, we have multiple choices:

- GNU Gfortran
- G95
- Intel ifort compiler
- Portland compiler
- Absoft ProFortran
- NAG Fortran Compiler

and for sure other which I may not be aware of. All of these compilers have pros and cons, so I am just for now selecting one in the pool only to continue the exposition. I am not selecting the trivial solution of Gfortran as most Linux distributions have it already packaged, and all the other required software as well (most complete distribution I am aware of for this is Fedora: all needed software is packaged and it is a matter of yum install).

So let us assume I have licensed the Intel Composer XE Professional Suite 13.0.0 on my laptop. My system administrator installed it on the default location under `/opt/intel`, and I have my shell environment update loading vendor provided script:

```
$> source /opt/intel/bin/compilervars.sh intel64
```

With some modification (the path, the script, the arguments to the script), same step is to be performed for all non-GNU compilers in the above list, and is documented in the installation manual of the compiler itself.

In case of Intel, to check the correct behaviour of the compiler, try to type the following command:

```
$> ifort --version
ifort (IFORT) 13.0.0 20120731
Copyright (C) 1985-2012 Intel Corporation.  All rights reserved.
```

I am skipping here any problem that may arise from license installation for any of the compilers, so I am assuming that if the compiler is callable, it works. As this step is usually performed by a system administrator on the machine, I am assuming a skilled professional will take care of that.

9.3 Environment setup

We will now use the `prereq_install` shell script provided in the `Tools/Scripts` directory. Given the above environment, we can edit the file and decomment the lines relative to the selected compiler.

```
# Working CC Compiler
#CC=gcc
CC=icc
#CC=pgcc
# Working C++ Compiler
#CXX=g++
CXX=icpc
#CXX=pgCC
# Working Fortran Compiler
#FC=gfortran
FC=ifort
#FC=pgf90
# Destination directory
DEST=/home/regcm/intelsoft
```

I am now ready to compile software.

9.4 Pre requisite library installation

The help script will build netCDF V4 and MPI libraries to be used to compile the RegCM model.

Then we can just execute the script:

```
$> ./prereq_install.sh
This script installs the netCDF/mpi librares in the

         /home/regcm/intelsoft

directory. If something goes wrong, logs are saved in

         /home/regcm/intelsoft/logs

Downloading ZLIB library...
Downloading HDF5 library...
Downloading netCDF Library...
Downloading MPICH2 Library...
Compiling MPI library.
Compiled MPI library.
Compiling zlib Library.
Compiled zlib library.
Compiling HDF5 library.
Compiled HDF5 library.
Compiling netCDF Library.
Compiled netCDF C library.
Compiled netCDF Fortran library.
Done!
To link RegCM with this librares use:

PATH=/home/regcm/intelsoft/bin:$PATH ./configure \
```

```
CC=icc FC=ifort \
CPPFLAGS=-I/home/regcm/intelsoft/include \
LDFLAGS=-L/home/regcm/intelsoft/lib \
LIBS="-lnetcdff -lnetcdf -lhdf5_hl -lhdf5 -lz"
```

The admins who must compile the pre requisite libraries are invited to look at the script, identifying the various steps. The normal user should be content of the last printout message which details how to use the just built libraries to compile RegCM model sources against. At run time an environment variable must be added to set correct paths:

```
$> export PATH=/home/regcm/intelsoft/bin:$PATH
```

The above is needed to be repeated for any shell which is used to run RegCM programs, and can be appended for convenience on the user shell startup scripts.

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